Historic, archived document

Do not assume content reflects current scientific knowledge, policies, or practices.

United States Department of Agriculture,
OFFICE OF EXPERIMENT STATIONS—Circular No. 59.
A. C. TRUE, Director.

PROGRESS REPORT OF COOPERATIVE IRRIGATION INVESTIGATIONS IN CALIFORNIA.

By S. FORTIER,
Irrigation Engineer, in charge of Pacific District.

AGREEMENT FOR COOPERATIVE INVESTIGATIONS.

For several years the Office of Experiment Stations of the United States Department of Agriculture has been prosecuting irrigation investigations in California. The first of these was made in 1900, in cooperation with the California Water and Forest Association, the results of which were embodied in Bulletin No. 100, of this Office, dealing with the general conditions of water titles and water appropriations in the State. Other investigations, principally of the duty of water in Sacramento and San Joaquin valleys and of drainage conditions around Fresno, were carried on in 1901 and 1902, the results being published in various reports of the Office. Owing to the limited funds available from the general funds of the Office for work in California, it was seen, in 1902, that unless additional means were provided from some source much irrigation work for which there was an urgent need in California would necessarily remain undone. At the same time it was seen that there was also an opportunity for profitably continuing hydrographic and forestry studies which had been carried on by other branches of the Federal Government, and for which there was also need of additional funds. A bill was therefore passed by the State legislature of 1903 providing for cooperation with the Federal Government in continuing these various lines of inquiry. By the terms of this bill the State Board of Examiners[1] was authorized, among other things, to cooperate with the Office of Experiment Stations of the United States Department of Agriculture "in ascertaining the best methods of distributing and using water" in irrigation. Ten thousand dollars was appropriated for carrying on this work during the biennial period beginning July 1, 1903, provided an equal sum should be furnished by the Office of Experiment Stations. In accordance with the act of the legislature, agreements were executed July 1, 1903, and July 1, 1904, between the Office of

---

[1] Consisting of the governor, the secretary of state, and the attorney-general.

Experiment Stations and the State Board of Examiners, under which cooperative irrigation investigations were begun in the summer of 1903 and are still in progress. The agreements of the two years were similar, both prescribing the work to be done and the methods of reporting and accounting. The agreement of July 1, 1904, under which the work is now being conducted, is as follows:

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF THE SECRETARY.

This agreement, made this 1st day of July, 1904, between the Director of the Office of Experiment Stations of the United States Department of Agriculture and the State Board of Examiners of California,

Witnesseth: The session of the legislature of the State of California in 1903 provided that—

"The State Board of Examiners is hereby empowered to enter into contract with the Director of the Office of Experiment Stations of the Department of Agriculture, for the purpose of ascertaining the best methods of distributing and using the water, to the extent of $10,000, provided that these expenditures for such purpose shall not be in excess of the amounts to be expended by this Department of the Federal Government in collaboration with this specific work."

Therefore, it is hereby agreed on the part of both parties to this contract that the work provided for in the State of California for the fiscal year beginning July 1, 1904, shall embrace studies of the duty of water in irrigation and the factors which influence it; studies of the methods of irrigation employed in California with a view to securing the adoption of better methods than those now in common use; studies of the best methods of organizing communities and districts to secure the stable and economical delivery of water to others; studies of methods of and cost of pumping water; studies of losses of water from canals and flumes through seepage and evaporation and the best means of alleviating the injuries caused.

The expenses of this investigation shall be paid equally by the two parties to this agreement, and shall include salaries of agents and employees, traveling and living expenses where the same are authorized by the United States Department of Agriculture, cost of instruments, apparatus, and equipment, and of preparing, illustrating, and printing reports of this investigation by the United States Department of Agriculture and bulletins giving progress reports of the investigation.

The usual forms of accounts and vouchers for payment of State and Government money shall be provided by the Office of Experiment Stations.

In all cases where a dispute may arise as to the meaning of this contract the provisions of "An act to provide for the joint investigations," etc., approved March 16, 1903, hereby referred to and made a part hereof, as far as applicable, shall control the construction of said contract, provided that nothing in this contract shall give authority to the Office of Experiment Stations of the United States Department of Agriculture to carry on any investigation not authorized by the United States statutes governing that office.

This work shall be carried out under the direction of the Office of Experiment Stations, United States Department of Agriculture.

Complete typewritten reports of the investigations carried on under this agreement shall be filed with the State Board of Examiners as work progresses or is completed.

This contract shall limit the liability of the State of California to $5,000 for the fifty-sixth fiscal year, and it is hereby agreed between the parties that this contract shall not become operative until approved by the Secretary of the United States Department of Agriculture and terminates on the 30th of June, 1905.

It is an express condition of this contract that no Member of or Delegate to Congress, or other person whose name is not at this time disclosed, shall be admitted to any share or interest therein or to any benefit to arise therefrom, and that said contract shall be subject in all respects to the provisions of sections 3739, 3740, and 3742 of the United States Revised Statutes so far as the same may be applicable.

In testimony whereof the parties hereunto have set their hands on the day, month, and year first above written.

STATE BOARD OF EXAMINERS,
(Signed) ALDEN ANDERSON,
Lieutenant and Acting Governor.
(Signed) C. F. CURRY, *Secretary of State.*
(Signed) C. N. POST,
Assistant Attorney-General.
OFFICE OF EXPERIMENT STATIONS,
(Signed) By WALTER H. EVANS,
Acting Director.

Approved:
(Signed) JAMES WILSON,
Secretary of Agriculture.

PUMPING WATER FOR IRRIGATION.

Work has been carried on in this branch of irrigation along the following lines: (1) Description of plants in use, (2) field tests of pumping plants in operation, (3) laboratory tests of typical pumps, and (4) duty and value of water under pumping plants. The first three lines have been in charge of Prof. J. N. Le Conte, of the University of California, assisted by Mr. A. J. Turner; and Mr. F. H. Tibbetts has collected a part of the data pertaining to the last line.

DESCRIPTION OF PLANTS IN USE.

An effort was made when the work was first planned to obtain by means of circular letters and personal visits a more or less complete description of existing plants. The information obtained in this way has been transcribed on cards which have been arranged in card indexes. The nature of the questions submitted to the owners of plants will be better understood by reading the accompanying forms, which represent the two sides of a card. Over 750 descriptions have been received to date, and of these about 500 contain valuable information on one or more of the following topics: The kind of plant in operation, the cost of fuel, the acreage watered, and the value of the crops produced.

Forms used in descriptions of pumping plants.

No. 751. Name---------- P. O. address----------
Location----------
Power -- { ------H. P. gasoline or distillate
------H. P. steam ----------
------H. P. electric motor----------
---------- }
Pump- { ------centrifugal----------
------piston ----------
------air lift ----------
---------- }
Total lift in feet-------- Rise and fall of water in well ----------
Make of engine ----------
Make of pump ----------
Capacity of pump---------- Cost of fuel----- $----------
Speed of pump---------- Cost of engine-- $----------
Cost of operation per day of 10 hours ----- { ---------- ---------- ---------- } Cost of pump--- $----------
Cost of well ---- $----------
Cost of erection $----------
Hours run per day-------- Total cost ----------
Cost of season's operation ---------- { ---------- ---------- } ----------Dia. suction----------
----------Dia. discharge----------
No. of days--------
Remarks ----------

(over.)

CROPS.

Acreage-------- Total-------- Water per acre----------
Acreage irrigated--------

	Acres.	Yield in tons per acre.		Value per ton.	Total value.
		Green.	Dry.		
Prunes					
Apricots					
Cherries					
Pears					
Peaches					
Grapes					
Apples					

System of ditch----------
Remarks ----------

FIELD TESTS OF PUMPING PLANTS IN OPERATION.

Tests have been made of 23 typical irrigation pumping plants in different parts of the State. It was hoped that by exercising care and good judgment in the selection of these the results would represent with considerable accuracy all of the better class of pumping plants in operation. The final results as tabulated give a record of 19 plants, the remaining 4 having been excluded on account of omissions or doubt as to their accuracy. Before beginning to make tests, the following instruments which were not in possession of the mechanical laboratory of the University of California, were either made or purchased:

Two steam engine indicators with attachments for indicating gas engines; 2 indicating wattmeters; 1 alternating current voltmeter; 1 60-pound pressure gage; 1 vacuum gage; 1 speed counter; 2 hydrometers; 1 level; 1 portable weir.

In each mechanical test it was necessary to determine the following factors: (1) The power developed within the engine or motor; (2) the amount of fuel or electrical energy used in maintaining this power for a given length of time and, in the case of a steam engine, the amount of water evaporated in the boiler; (3) the market value of fuel or electrical energy; (4) the gage head against which the pump is operating; (5) the total measured lift of the pump, and (6) the volume of water pumped in a given time. Brief descriptions of a few of the plants tested, with a summary of the results obtained in each case, are herein given.

TEST NO. 1.

The first plant tested consisted of a 35-horsepower gasoline engine and a No. 5 single runner, vertical centrifugal pump, located in the Santa Clara Valley and owned by Mrs. S. L. Winchester. It represented one of the best as well as one of the most common types of plants in which a gasoline engine is the source of power. In this class the pump is placed at the bottom of a rectangular pit, whose depth is dependent on the plane of the ground water; from 1 to 6 wells are sunk from the bottom of the pit to depths which vary from 150 to 250 feet. In this plant the suction pipes are about 40 feet long and considerably larger than the pump inlet. A check valve is inserted immediately above the discharge opening, and the discharge pipe is increased from one and one-half to two times the diameter of the opening. The shaft is vertical and supported at intervals by bearings, and the engine is belted with a single quarter-turn belt.

Summary of results of test No. 1.

	Minimum.	Maximum.	Average.
Quantity of 48° engine distillate at 0.794 density used, in gallons per hour			5.65
Cost of distillate per hour			$0.6757
Revolutions of engine per minute	210	216	
Revolutions of pump per minute	700	730	
Explosions of engine per minute	99	108	
Total mean lift of water, in feet			69
Total mean lift of water, including friction, in feet	75.9	76.8	
Discharge of pump per minute, in gallons	969	988	
Useful work done in raising water, in horsepower	17.3	19.1	18.86
Power developed within cylinder of engine, in horsepower			36.48
Combined efficiency of engine and pump, per cent			51.70
Cost of fuel for raising 1,000,000 gallons 1 foot			$0.1675
Cost of fuel for raising 1 acre-foot of water 1 foot			$0.055
Cost per acre of fuel for raising water 30 feet to irrigate land 18 inches deep			$2.48

TEST NO. 3.

This test also was made on a gasoline plant located in Santa Clara Valley, but owing to a number of defects the combined efficiency of engine and pump was 39 per cent instead of 51.7 per cent, as in the former case. The causes which produced the low efficiency were: (1) An excessive amount of oil was consumed by the engine; (2) the intervention of a jack shaft in the belting wasted power needlessly; (3) short radius elbows in the discharge pipe increased the friction; (4) the water was lifted 1 foot too high.

Summary of results of test No. 3.

	Minimum.	Maximum.	Average.
Quantity of 48° distillate at 0.794 density used, in gallons per hour			3.76
Cost of distillate per hour			$0.45
Revolutions of engine per minute	183	189	
Revolutions of pump per minute	730	765	
Explosions of engine per minute	74	94	81.2
Total mean lift of water, in feet			89
Total mean lift of water, including friction, in feet	91.4	94.7	93.5
Discharge of pump per minute, in gallons	330	347	338.4
Useful work done in raising water, in horsepower			8
Power developed within cylinder of engine, in horsepower			20.24
Combined efficiency of engine and pump, in per cent			39
Cost of fuel for raising 1,000,000 gallons 1 foot			$0.25
Cost of fuel for raising 1 acre-foot of water 1 foot			$0.08
Cost per acre of fuel for raising water 30 feet to irrigate land 18 inches deep			$3.60

TEST NO. 9.

One of the large gasoline plants tested, one of the highest in general efficiency, was that of the Chase Nursery Company, of Riverside, Cal. This plant consists of a 75-horsepower gasoline engine and a triplex-plunger pump. Owing to excessive vibrations, the engine could not be satisfactorily indicated, but the combined efficiency of both engine and pump was over 70 per cent.

Summary of results of test No. 9.

	Minimum.	Maximum.	Average.
Quantity of 44° distillate at 0.80 density used, in gallons per hour			8.27
Cost for distillate per hour			$0.785
Revolutions of engine per minute	285	298	
Revolutions of pump per minute	39½	39½	39½
Total mean lift of water in feet			195
Total mean lift including friction, in feet	196.7	196.7	196.7
Discharge of pump per minute, in gallons			868
Cost of fuel for raising 1,000,000 gallons 1 foot			$0.0775
Cost of fuel for raising 1 acre-foot of water 1 foot			$0.0250
Cost per acre of fuel for raising water 30 feet to irrigate land 18 inches deep			$1.13

TEST NO. 10.

This plant, which is owned by the Sunnyside Water Company and located near Porterville, in Tulare County, is representative of a large number of plants in which electric motors are the source of power. A 50-horsepower induction motor is coupled direct to a No. 4 compound, horizontal, centrifugal pump. Three 6-inch suction pipes are inserted in 10-inch wells, which vary from 140 to 150 feet in depth. The motor and pump on one base are placed at the bottom of the pit. Power is furnished by a long-distance transmission line at the flat rate of $50 per horsepower per annum. No reduction is made for the time the plant is not running. In the following summary the cost for electric energy is based on the assumption that the plant is operated 5,000 hours per year, and the cost of 1 kilowatt hour is thus 1.34 cents. If the plant is operated only 2,500 hours the cost per hour would be doubled.

Summary of results of test No. 10.

	Minimum.	Maximum.	Average.
Amount of electric energy, in kilowatt hours			26.57
Cost of electric energy, per kilowatt hour			$0.355
Revolutions of pump per minute	868	876	
Total lift of water, in feet			150
Total lift including friction, in feet	153.1	153.7	153.6
Discharge of pump per minute, in gallons	388	388	338
Useful work done in raising water, in horsepower			15.04
Combined efficiency of motor and pump, in per cent			42
Cost of electric energy of raising 1,000,000 gallons of water 1 foot			$0.1025
Cost for electric energy of raising 1 acre-foot of water 1 foot.			$0.0325
Cost per acre of electric energy for raising water 30 feet to irrigate land 18 inches deep			$1.46

TEST NO. 18.

The pumping plant used in test No. 18 represents the better class of those in which a steam engine is used. It is located in the Willowglen district of Santa Clara County, and is owned by Mr. Henry Booksin, who makes use of the water which is pumped to irrigate 50 acres of prunes and cherries. The plant consists of a 75-horsepower Corliss steam engine and a No. 6 single-runner, vertical, centrifugal pump, belted direct with a quarter-turn belt 27 feet between centers. The water is discharged into a tank from which it flows through a 12-inch pipe to the distributing system. There are five suction pipes in two pits. The fuel used is crude oil, 16.6 degrees Baume test, and 0.956 density, costing 75 cents per barrel of 42 gallons.

Summary of results of test No. 18.

	Minimum.	Maximum.	Average.
Quantity of crude oil used, in gallons per hour			19.6
Cost of crude oil per hour			$0.35
Revolutions of engine per minute	113	116	114.6
Revolutions of pump per minute	512	520	
Water evaporated per hour, in pounds			1,682
Total mean lift of water, in feet			54.75
Total mean lift including friction, in feet	59.3	60.7	59.85
Discharge of pump per minute, in gallons	1,628	1,669	1,653
Useful work done in raising water, in horsepower			25
Power developed within cylinder of engine, in horsepower			50.61
Combined efficiency of engine and pump, in per cent			48
Cost of fuel for raising 1,000,000 gallons 1 foot			$0.065
Cost of fuel for raising 1 acre-foot of water 1 foot			$0.02
Cost per acre of fuel for raising water 30 feet to irrigate land 18 inches deep			$0.90

LABORATORY TESTS OF TYPICAL PUMPS.

The results of tests of typical pumps made by Professor Le Conte in the mechanical laboratory of the University of California demonstrate that for every speed of pump there is a definite head at which the pump works at its highest efficiency, and that conversely, for a given head there is a definite speed which is most effective for the economical operation of the pump. This was determined by running the pump at various speeds and varying the head so as to secure the maximum efficiency in each case. From the efficiencies thus obtained it is seen that up to a certain limit, an increase of speed is followed by a decrease in efficiency. The results in the following table summarize the test of a No. 4 single-runner, horizontal, centrifugal pump.

Heads giving highest efficiency for given rates of speed.

Revolutions of pump per minute.	Lowest head.	Highest head.	Head giving highest efficiency.	Efficiency of pump.
	Feet.	*Feet.*	*Feet.*	*Per cent.*
550	15.6	18.8	17	63.2
696	20.7	30.8	25.4	67.6
800	26.0	39.7	28.5	69.2
893	32.2	52.3	40.6	70.9
1,004	34.8	63.9	51.4	69.4
1,102	35.5	76.1	61.3	68.9

This shows that the maximum working efficiency of this pump occurred when pumping against a head of 40 to 50 feet, with a speed of from 900 to 1,000 revolutions per minute.

Tests made to determine whether the efficiency of a pump working under a definite head and speed is affected by the way in which the head is distributed between the suction and the discharge gave the highest efficiency for the low suction heads as shown below. This being true with a pump which is well packed, it is obvious that a pump imperfectly packed under a high suction head would perform little useful work.

Results of tests made to determine effect of change in suction head.

Revolutions of pump per minute.	Discharge head.	Suction head.	Total head.	Efficiency.
	Feet.	*Feet.*	*Feet.*	*Per cent.*
893	23.8	16.2	40	68.3
893	18.9	21.1	40	67.2
893	13.9	26.1	40	66.9
893	9.2	30.8	40	64.4

The following results were obtained from a test made of a single-acting, triplex pump of a two-standard style. The efficiency increases rapidly with the head, owing doubtless to the tight packing. The pump was tested in the condition in which it was received from the manufacturer.

Efficiency of pump under varying head.

Speed of pump.	Total head.	Efficiency.
Strokes per minute.	*Feet.*	*Per cent.*
64.8	32.4	33.8
64.8	76.2	54.8
64.6	122.5	63.3
63.4	168.5	68.4
64.8	215.0	71.4
64.6	261.0	76.6
64.5	307.2	74.5

THE DUTY AND COST OF WATER UNDER PUMPING PLANTS.

During 1904 the duty of water, under 70 pumping plants which supplied water to 2,730 acres of orchards in the Santa Clara Valley, was determined. In 34 of the 70 plants the power was derived from stationary steam engines, in 24 from gasoline engines, in 11 from portable steam engines, and in 1 from an electric motor. The capacities varied from less than 100 gallons per minute to over 1,000 gallons per minute. In measuring the water discharged by the pump, permanent weir boxes were installed in a number of cases, from which continuous records might be obtained for several years. In the majority of cases, however, the limited funds would not permit the use of anything more costly than a weir board having a notch of the trapezoidal or Cipolletti form. The equivalent flow in gallons per minute for any given length of weir and depth of water over the crest was obtained from the following table:

Discharge over Cipolletti weirs.

Depth of water on crest.	1-foot weir.		1½-foot weir.		2-foot weir.		3-foot weir.	
Inches.	*Cubic feet per sec.*	*Gals. per minute.*	*Cubic feet per sec.*	*Gals. per minute.*	*Cubic feet per sec.*	*Gals. per minute.*	*Cubic feet per sec.*	*Gals. per minute.*
1	0.08	36	0.12	55	0.16	73	0.24	109
1⅛	0.10	44	0.15	65	0.19	87	0.29	130
1¼	0.11	51	0.17	76	0.23	101	0.34	152
1⅜	0.13	59	0.20	88	0.26	117	0.39	175
1½	0.15	67	0.22	100	0.30	139	0.45	200
1⅝	0.17	75	0.25	113	0.34	150	0.50	226
1¾	0.19	84	0.28	126	0.38	168	0.56	252
1⅞	0.21	93	0.31	140	0.42	187	0.62	280
2	0.23	103	0.34	154	0.46	206	0.68	308
2⅛	0.25	113	0.38	169	0.50	225	0.75	338
2¼	0.27	123	0.41	184	0.55	245	0.82	368
2⅜	0.30	133	0.44	199	0.59	266	0.89	399
2½	0.32	144	0.48	215 .	0.64	287	0.96	431
2⅝	0.34	154	0.52	231	0.69	309	1.03	464
2¾	0.37	166	0.55	248	0.74	332	1.11	497
2⅞	0.39	177	0.59	262	0.80	355	1.18	531
3	0.42	189	0.63	283	0.84	378	1.26	566
3⅛	0.45	201	0.67	301	0.90	402	1.34	602
3¼	0.47	213	0.71	319	0.95	426	1.42	639
3⅜	0.50	225	0.75	338	1.00	451	1.51	676
3½	0.52	238	0.80	357	1.06	476	1.59	714
3⅝	0.56	251	0.84	376	1.12	502	1.68	753
3¾	0.59	264	0.88	396	1.18	528	1.76	792
3⅞	0.62	277	0.93	416	1.24	554	1.85	832
4	0.65	291	0.97	436	1.30	582	1.94	872
4⅛	0.68	304	1.02	456	1.36	609	2.04	913
4¼	0.71	319	1.07	478	1.42	637	2.13	956
4⅜	0.74	333	1.11	499	1.48	665	2.22	998
4½	0.77	347	6.16	521	1.55	694	2.32	1,041
4⅝	0.81	462	1.20	543	1.61	723	2.42	1,084
4¾	0.84	376	1.26	564	1.68	753	2.52	1,129
4⅞	0.87	391	1.31	587	1.74	782	2.62	1,174
5	0.91	406	1.36	609	1.81	813	2.72	1,219
5⅛	0.94	422	1.41	633	1.88	843	2.82	1,266
5¼	0.97	437	1.46	656	1.95	874	2.92	1,312
5⅜	1.01	453	1.51	679	2.02	906	3.03	1,359
5½	1.05	469	1.57	703	2.09	938	3.13	1,407
5⅝	1.08	485	1.62	727	2.16	970	3.24	1,455
5¾	1.12	501	1.68	752	2.23	1,002	3.35	1,503
5⅞	1.15	517	1.73	776	2.31	1,034	3.46	1,553
6	1.20	534	1.79	801	2.38	1,069	3.57	1,603
6⅛	----------	----------	----------	----------	2.46	1,102	3.68	1,653
6¼	----------	----------	----------	----------	2.53	1,136	3.80	1,704
6⅜	----------	----------	----------	----------	2.61	1,170	3.91	1,755
6½	----------	----------	----------	----------	2.68	1,205	4.03	1,807
6⅝	----------	----------	----------	----------	2.76	1,240	4.14	1,859
6¾	----------	----------	----------	----------	2.84	1,275	4.26	1,912
6⅞	----------	----------	----------	----------	2.92	1,310	4.38	1,966
7	----------	----------	----------	----------	3.00	1,346	4.50	2,020

YIELD AND VALUE OF CROPS IRRIGATED FROM PUMPING PLANTS.

The area irrigated in a given time by a particular plant was usually determined by measuring the distance between the rows of trees and counting the number of trees in the tract. In the results of the 12 plants included in the following table, on only one orchard was more than 24 inches in depth over the surface used. On some orchards from 6 to 9 inches was used. The average depth for all of the plants was 15 inches.

While collecting information on the amount of water used, an effort was made to ascertain from the owners or operators the amount of the principal items of cost in operating each plant. The items considered were fuel, attendance, and incidentals. The cost of raising 1 acre-foot of water 1 foot, as given in the seventh column of the table below, was, in many instances, high when compared with the plants of high efficiency, but the figures as given represent fairly well the cost with the average plant. On the basis above named, the average cost for the season of irrigation under pumping plants was about $6 per acre.

Duty and cost of water during the season of 1904 under 12 typical pumping plants in Santa Clara Valley, California.

Area in orchard.	Lift.	Depth of water applied.	Total applied in 1904.	Total cost.	Cost per acre-foot.	Cost for raising 1 acre-foot 1 foot.	Cost per acre.
Acres.	*Feet.*	*Feet.*	*Acre-feet.*				
70.00	19.5	1.00	70.0	$176.90	$2.53	$0.130	$2.53
21.00	55.0	.79	16.6	102.10	6.15	.110	4.86
150.00	110.0	2.10	315.0	1,575.00	5.00	.045	10.50
75.00	73.0	.89	66.7	828.00	12.41	.170	11.04
17.00	100.0	1.26	21.4	77.50	3.62	.036	4.56
23.50	140.0	.57	13.4	137.10	10.23	.073	5.83
25.00	28.0	1.55	38.7	149.10	3.85	.138	5.96
15.00	28.0	.97	14.5	55.90	3.86	.138	3.73
30.00	22.0	1.05	31.5	113.10	3.59	.163	3.77
150.00	44.0	1.06	159.0	370.00	2.33	.053	2.47
30.00	23.0	.49	14.7	88.00	5.99	.260	2.93
24.25	115.0	.85	20.6	116.30	5.65	.050	4.80

The following table gives some of the data collected from the owners of the pumping plants included in the previous table. The figures represent the gross income and are based on the average returns of the last three seasons.

Table showing yield and value of irrigated fruit crops.

Variety of fruit.	Area irrigated.	Yield per acre.	Price per ton.	Value per acre.	Total value.
	Acres.	*Tons.*			
Prunes	36	4.85	$27.50	$133.33	$4,802
Do	21	4.75	40.00	190.00	3,990
Do	70	4.55	25.00	113.75	7,963
Apricots	45	4.50	30.00	135.00	6,075
Cherries	10	2.00	80.00	160.00	1,600
Peaches	25	5.00	25.00	125.00	3,125
Prunes, cherries, apricots	75				3,600
Apricots	4¼				350
Peaches	3				300
Cherries	3				300
Prunes	5¾				550
Do	22	2.10	19.00	39.90	878
Apricots	15	7.34	18.18	133.44	2,002
Cherries	25	1.00	100.00	100.00	2,500
Peaches	30	5.00	25.00	125.00	3,750
Pears	105	8.00	30.00	240.00	25,200
Plums	45	6.00	25.00	150.00	6,750
Prunes	14	5.00	20.00	100.00	1,400
Peaches	11	5.00	40.00	200.00	2,200
Apricots	5	4.00	35.00	140.00	700
Do	2¾				500
Peaches	1½				200
Cherries	1½				450
Prunes	18½				1,350
	594¼				80,535
Average value per acre					136

THE LOSS OF WATER BY EVAPORATION.

Evaporation annually deprives the California farmer of a large amount of water which he might utilize to good advantage. By this process water is withdrawn from the surfaces of storage lakes and reservoirs, irrigation canals, and flooded fields. By the same process moisture is continually passing from the surface of fields, whether irrigated or farmed dry.

For the past eighteen months experiments have been conducted for the most part in iron tanks filled with either water or soil, to determine the amount of loss by evaporation and the influences which affect it. The ultimate purpose of the investigation has been to discover practical means of lessening this enormous loss.

EVAPORATION FROM A WATER SURFACE.

The monthly evaporation from tanks filled with water and placed in earth at each of the places named is given in the following summary. Similar observations are now being carried on at Berkeley and Chico. It was thought that these five stations would represent the prevailing climatic conditions of the irrigated portions of the State.

Summary of evaporation losses from water surfaces, at Tulare, Pomona, and Calexico, Cal., from July 1, 1903, to July 31, 1904.

Month.	Tulare.	Pomona.	Calexico.
1903:	*Inches.*	*Inches.*	*Inches.*
July	----------	9.07	14.48
August	12.34	9.37	12.72
September	9.05	6.29	10.29
October	6.32	6.63	7.50
November	3.51	4.25	4.80
December	2.00	2.51	4.52
1904:			
January	1.46	2.78	4.39
February	2.98	2.57	6.32
March	1.77	3.69	8.86
April	3.75	5.00	9.55
May	8.64	6.50	10.91
June	10.66	8.20	13.89
July	12.20	----------	----------
Total	74.68	66.92	108.23

At Calexico, in the Imperial Valley, the weekly evaporation in January was never less than seven-eighths of an inch, and in June and July it was occasionally as high as 3⅜ inches. At Pomona the lowest weekly evaporation occurred in February and was less than one-half inch, while in July it was 3 inches. At Tulare, in midsummer, the greatest loss per week was about 3¼ inches, and in midwinter, during periods of frost and fogs, there was little, if any, loss. Since the station was established at Berkeley, the greatest loss occurred between September 10 and September 17, when it was 1¼ inches. The weekly loss in November averaged three-eighths of an inch.

THE INFLUENCE OF TEMPERATURE ON EVAPORATION.

An experiment was carried on in the summer of 1904 at Berkeley to determine the effect of temperature on the rate of evaporation. For this pupose six tanks were used. Ice and sawdust were packed around two tanks to lower the temperature, and oil lamps were kept burning continuously beneath two others to raise the temperature. The remaining two tanks represented natural conditions. The following summary, which gives in brief the average results, confirm the records obtained from different parts of the State, viz, that the amount of evaporation is largely dependent on the temperature of the water.

Summary of average weekly losses by evaporation, with varying temperatures of water, at Berkeley, Cal., in July and August, 1904.

Temperature of water.	Weekly evaporation.
Degrees Fahrenheit:	*Inches.*
55.5	0.42
62.0	.77
69.2	1.54
80.1	3.08
89.2	3.92

EVAPORATION FROM SOILS.

Similar experiments have been conducted during the past year and a half for the purpose of gaining more definite information in reference to the rate of evaporation from cultivated soils. For lack of time the results have not been compiled, but the records seem to show that this question is complex in its character. The loss of water from this cause would seem to depend on the amount of moisture in the soil and its temperature. It is likewise influenced by the character of the soil, condition of the atmosphere, wind, etc. It may be stated in a general way that the loss from June 1 to October 1 on bare irrigated soil in southern California was from 1 to 2 inches per month. Assuming that the price of one-fifth of a miner's inch is $6 for the season, the loss from this cause would annually amount to from $2 to $4 for each one-fifth of a miner's inch.

THE EFFECT ON EVAPORATION OF SURFACE, SHALLOW FURROW, AND DEEP FURROW IRRIGATION.

Typical soils from Redlands, Riverside, Fullerton, and Pomona have been placed in tanks at the Pomona station under the charge of Mr. J. H. Barber. Each kind of soil has been irrigated in three ways to correspond with the different methods: (1) In which the surface is flooded; (2) with shallow, and (3) with deep furrow methods, in which water is applied at the bottom of furrows 3 and 12 inches deep, respectively. The results thus far indicate that surface flooding is most wasteful and that deep furrows conserve much more water than do shallow furrows. The average amounts evaporated under each method during September and October, 1904, were as follows:

Average evaporation from soil during September and October, 1904, under different methods of irrigation.

	Cubic feet per acre.
Surface irrigation	6,428
Shallow furrow irrigation	5,581
Deep furrow irrigation	4,811

RELATION OF SOIL MOISTURE TO PLANT GROWTH.

The effect of water on the growth and yield of cereals on the worn-out soils of the San Joaquin Valley has been tried. In experimenting with barley the yield with natural rainfall alone produced at the rate of 9 bushels per acre, while the application of 16 inches of water increased the yield to 22 bushels per acre. In the case of wheat a field receiving only the natural rainfall, amounting to 4½ inches, produced straw but no grain. A field receiving 4 inches of water in addition to the rainfall produced at the rate of 10 bushels, and 16 inches of water increased the yield to 38 bushels.

THE VALUE OF IRRIGATION IN FRUIT GROWING.

Conclusions concerning the desirability and efficiency of irrigation arrived at by irrigators upon the basis of their experience in the use of water may be properly regarded as a valuable supplement to data secured by more exact methods of investigation. For this reason a careful and comprehensive inquiry has been undertaken by Prof. E. J. Wickson, of the University of California, to ascertain the empirical results of irrigation in fruit growing as measured by the character and quantity of the products and their suitability for several leading commercial purposes. Brief statements of the object of the inquiry and schedules of a few leading questions were prepared and correspondence was begun with upwards of 200 fruit growers, shippers, canners, and driers throughout the irrigated States of the Pacific coast, viz: Idaho, Washington, Oregon, California, and Arizona. The interest manifested by these persons and the freedom with which they contributed the results of their experience and observation were very gratifying. A full report collating and arranging these results and commenting upon their significance is now awaiting publication.

The first inquiry was with reference to the quantity of the product as affected by irrigation. All responses from strictly arid localities where irrigation is essential to the growth of fruits were excluded, and only evidence from semiarid localities, where one really has a choice between irrigation and nonirrigation, was used in reaching a conclusion. This inquiry led to the conclusion that irrigation, as supplementary to rainfall, is effective in increasing the product from 10 to 100 per cent, according to local conditions of soil and rainfall.

The second inquiry was as to whether irrigation increased the regularity of bearing, and in this respect 44 growers testified emphatically in the affirmative, citing instances. Four were doubtful or negative, and this negation is explained by the fact that the orchards are located on lands which secure more than average moisture by underflow or other natural causes or conditions.

The third inquiry was with reference to the general qualities and commercial characters of irrigated fruit, and testimony naturally was sought from all the regions where any amount of water was artificially applied. The numerical result was that 87 growers maintained, in many cases with specific details, the superiority of irrigated fruits. Only 5 dissented, and their doubt may be explained upon the ground that water was used wrongly or that the rainfall was ample. The significance of the testimony is freely discussed in the report. Three phases of the superiority of irrigated fruit were separately inquired into and are discussed, viz, suitability (a) for long-distance shipment, (b) for canning, and (c) for drying. In all these commercial uses of fruit direct inquiry was made among fruit shippers, canners, and driers, as well as among the growers themselves. The result was the fullest demonstration of the value of irrigation in securing that full and perfect development of fruit which best promotes the success of the several trade and preserving enterprises which have attained such great development upon the Pacific coast. Interesting statements are also made of the success of irrigated fruits at great expositions, where direct comparison has been made with the fruit of the rainfall districts and where the superior size, quality, and desirability of irrigated fruits grown in the dry air and full sunshine of the arid region was strikingly demonstrated. The investigation was concluded with an inquiry into alleged injuries to fruits and to vines by irrigation, resulting in full demonstration that such effects are due to errors in irrigation and not to irrigation itself. Though this claim is not new, the establishment of it by the testimony of a large number of growers is pertinent and significant.

METHODS OF PREPARING LAND AND APPLYING WATER.

In general, the irrigators of Western America follow four methods of applying water to land, viz, the check method, flooding from field ditches, the furrow method, and the basin method. Each of these systems is particularly suited to certain conditions which should govern its adoption, but which too often are hardly considered at all. It is more common for each settler in a new district to either adopt the method common to his old environment, regardless of whether it is the best one for the new conditions, or blindly follow the method already in vogue in the new district, when perhaps the method he is already used to could be applied with profit. As a part of these cooperative irrigation investigations in California, data have been collected in many parts of the State as to the best practice, not only in applying water to land, but also in preparing the land to receive the water. These data have recently been published, along with similar data from all the Western States, as Bulletin No. 145 of the Office of Experiment Stations. The publication, in one volume, of such data from so wide a range of sources enables comparison to be made of all the systems and offers a practical guide to the selection of the one best suited to the given conditions.

THE CHECK METHOD.

Experience of irrigators has demonstrated that the check method is best adapted to a light, sandy soil having a comparatively even slope of from 3 to 15 feet per mile. On the other hand, it has been shown that a field having a steep slope should not be checked, since such checking would require the levees to be made so high and steep and so close together that farming operations would be rendered difficult and a large part of the field withdrawn from crop production. After summing up and describing these various conditions, Bulletin No. 145 states the advantages and disadvantages of this method as follows:

ADVANTAGES.

(1) One irrigator can attend to a large volume of water, and can irrigate from 7 to 15 acres in ten hours, making the cost of applying water less than by any other method.

(2) Certain soils can not be successfully irrigated by any other method.

(3) It is well adapted to forage crops on flat slopes.

(4) The cost of preparing the land for irrigation is small after the first year.

(5) The amount applied can be more readily gaged.

DISADVANTAGES.

(1) Much of the surface soil is removed to form levees.

(2) The yield is decreased where the top soil has been removed, except in deep alluvial soil.

(3) Mowers, reapers, and other implements are frequently damaged by high levees.

(4) It is not well adapted to rotation of crops.

(5) The method must be limited to particular crops and to flat slopes.

(6) It costs for the first year from $7 to $20 per acre to prepare the land.

(7) Drainage for surplus water must be provided.

(8) Some soils bake after being flooded.

FLOODING FROM SMALL FIELD DITCHES.

Of the 9,000,000 or more acres of land being irrigated in the West, probably three-fifths are flooded from small field ditches, yet in certain sections of California, as portions of San Joaquin Valley, this method is unknown. In a general way it may be stated that it is suited to the irrigation of all kinds of grains and grasses. Its advantages and disadvantages are summarized below.

ADVANTAGES.

(1) In the first cost it is one of the cheapest methods.

(2) It is well adapted to the most common crops.

(3) Apart from grading, the top soil is not disturbed.

(4) The small field ditches do not seriously interfere with farming operations.

(5) It readily adapts itself to the delivery of water in continuous streams.

(6) Enormous yields have been obtained by the use of this method.

DISADVANTAGES.

(1) The labor required to handle the water is both fatiguing and excessive.

(2) One man can not thoroughly irrigate on an average more than 3 acres in ten hours.

(3) It is difficult to control the irrigation stream after dark.

(4) In all grain crops the field ditches have to be renewed each spring.

(5) It is difficult to distribute the water evenly over the surface.

(6) The yield is not uniform when the water is unevenly distributed.

FURROW IRRIGATION.

Furrow irrigation is found to be the best for the large majority of orchards and for all root crops and vegetables. Experience of irrigators shows the following to be its principal advantages and disadvantages.

ADVANTAGES.

(1) The loss of water due to evaporation and seepage is small.

(2) Alkali is less liable to rise.

(3) A small head can be conveniently and advantageously used.

(4) There is little displacement of the top soil.

(5) The soil is moistened chiefly from beneath the surface by capillarity.

(6) The surface soil after being watered is not baked, nor hard to cultivate.

DISADVANTAGES.

(1) Large volumes of water can not be rapidly applied to a field.

(2) As commonly practiced, the flow in the furrows is unequal.

(3) It is difficult to distribute the water uniformly on porous soils.

(4) The upper and lower ends of a tract seldom receive equal amounts of water.

THE BASIN METHOD.

This method differs from the check method merely by having the levees small, temporary "borders," thrown up, perhaps, by a "ridger," rather than permanent levees, and in having the "basins" very much smaller than the "checks." The use of "basins" is confined for the most part to orchard irrigation, where a "basin" is usually made for each tree, but its use seems to be decreasing rather than increasing. The best conditions for this method are a plentiful supply of water during the time of irrigating and soils that can not properly be watered from furrows. It has the following advantages and disadvantages:

ADVANTAGES.

(1) It permits the use of a large head of water on small tracts.

(2) The time required for applying water is much reduced.

(3) It is well adapted to light, porous soils.

(4) It is applicable to tracts containing soils of widely different texture.

(5) Flood waters may be utilized.

DISADVANTAGES.

(1) Heavy soils are apt to bake after being flooded.
(2) It necessitates considerable shifting of soil for each irrigation.
(3) There is considerable loss from evaporation.
(4) It tends to form a hardpan beneath the cultivated layer.
(5) It may bring the roots of trees near the surface.
(6) The water may chill the trees in winter and scald them in summer.

DISTRIBUTION AND USE OF WATER IN MODESTO AND TURLOCK IRRIGATION DISTRICTS.

In March, 1904, Mr. Frank Adams, of this Office, was detailed to make a study of conditions in Modesto and Turlock irrigation districts, in Stanislaus and Merced counties, with the general purpose of aiding these districts in the solution of some of the problems of irrigation with which they were confronted on the recent completion of the canal systems. During the season of 1904 Mr. Adams spent nearly five months in these districts, and a beginning was made in measuring the water diverted and used and in gathering such facts as would assist these districts in the organization of the best systems of water delivery and distribution. A report of the work is now in hand. The studies embraced the principal irrigation problems with which the districts have to deal at this time. One of the most important of these is the question of how much water is needed for the proper growth of an acre of alfalfa or other crop in these districts. An answer to this question is necessary to the proper planning for the future and as a guide to intending settlers. The measurements along this line made in 1904 were for the purpose of ascertaining how much water is being diverted and used at the present time. They show that during this year the duty of water was very low, owing partly to the fact that large areas of the land were placed under irrigation for the first time, and largely to the further fact that very wasteful use was more the rule than the exception. Taking the average for the whole season, each cubic foot of water per second diverted from Tuolumne River at La Grange Dam by Modesto Canal served only 41 acres, and each cubic foot diverted by Turlock Canal served only 65 acres. When it is remembered that 1 miner's inch to 5 acres, or 1 cubic foot per second to 250 acres, is a very common duty in southern California, it is seen that there is great opportunity for improvement here. The people of Modesto and Turlock districts must study the economical use of water if, with the means they have provided or contemplate, they are to irrigate the quarter of a million acres now embraced in the districts.

LOSSES BY SEEPAGE.

All canals, except those having cemented sides and bottoms, are subject to losses from seepage, often so great as to bring disaster to irrigation enterprises. A determination was made of the losses in sections of both Modesto and Turlock canals in 1904. From La Grange Dam, the point of diversion for both canals, to Waterford, a distance of 22 miles, Modesto Canal lost during the season 15.5 per cent of the amount diverted, which was equal to a continuous flow through the season of 26 cubic feet per second. From La Grange Dam to the head of Lateral No. 6, a distance of 33 miles, the loss during one series of measurements in June was 21.5 per cent of the amount diverted, equivalent to a flow of 56 cubic feet per second. From La Grange Dam to Hickman, a point on Turlock Canal 22 miles below the headgate, the loss during the season was 18 per cent of the amount diverted, or a continuous flow of 55 cubic feet per second. While these losses are not excessive under the conditions present, both districts are taking steps to lessen them by the construction of improved canal sections and structures in portions of the systems.

RECORDS OF CANAL FLOWS.

Another important feature of the work in Modesto and Turlock districts was the keeping of records as a basis for water distribution and delivery. Measuring stations were established and maintained on both Modesto and Turlock canals at the headgates and at other points, records of flow in each main canal being furnished daily to the local papers in Modesto, thus enabling every irrigator in the districts to be constantly informed of the state of the water supply. At the close of the season and with the results of 1904 as a basis, systems of keeping records in the future were outlined and arrangements made for assisting the districts in carrying these systems into effect at once.

ORGANIZATION OF IRRIGATION DISTRICTS.

The remaining features of the work were studies of the organization and formative periods of the districts; of the best methods of applying water to land; of the crops grown, and of the rise of ground water due to the gradual filling of the subsoil. In the latter connection the report of Mr. Adams shows that the districts must be prepared to deal with the problem of drainage in certain sections at no distant date.

PUBLICATIONS.

The following publications relating to irrigation investigations in California have been issued by the Department or are in course of preparation by the Office of Experiment Stations:

Preparing Land for Irrigation and Methods of Applying Water. By agents of Irrigation Investigations. This bulletin is the first to be issued under agreement with the State Board of Examiners for cooperative irrigation investigations. Five thousand copies were set aside for distribution in California and a large number have already been sent out. Pp. 84, pls. 7, figs. 33. (Bulletin No. 145, Office of Experiment Stations.)

Pumping Water for Irrigation. This report, which will be issued early in 1905, will embody chiefly results of pumping investigations in California, but will also contain results of work on similar lines in Colorado, Nebraska, Kansas, Arkansas, Texas, and New Mexico. That part of the report covering the field and laboratory tests of pumping plants used in irrigation in California has already been completed by Prof. J. N. LeConte, of the department of mechanical engineering of the University of California, and is being withheld from publication pending the completion of the other reports.

Results of Tank Experiments in Irrigation. This report will not be published until the results for the season of 1905 are available. It will have to do with the relation of soil moisture to plant growth and to the losses of water by evaporation from both soil and water surfaces.

The Distribution and Use of Water in Modesto and Turlock Irrigation Districts, California. By Frank Adams, irrigation assistant. This bulletin will contain about 45 pages, and will be illustrated.

Irrigation Conditions in Imperial Valley, California. By J. E. Roadhouse, agent and expert. This report will be embodied in general reports of irrigation and drainage investigations.

Duty of Water under Gage Canal, California. This report was begun by the late W. Irving, C. E., chief engineer of the Gage Canal system, and is being completed by J. M. Mylne. It will be embodied in general reports of irrigation and drainage investigations.

The Relation of Irrigation to the Yield, Size, Quality, and Commercial Suitability of Fruits. By E. J. Wickson, professor of agricultural practice in the University of California, and horticulturist of the California Agricultural Experiment Station. The report is based on information obtained by correspondence from a large number of fruit growers in California and elsewhere on the Pacific coast. (In preparation.)

WORK PLANNED FOR 1905.

The field for profitable irrigation study in California from the standpoint of the farmer and new settler is so large that there is no little difficulty in selecting for 1905 that work which will be most practical and hence most fruitful of results. Many of the questions that are now being asked about irrigation in California will require for their answer long experience on the part of irrigators and long study on the part of the investigators; yet, through its desire and need for thrifty immigrants to settle its great agricultural areas, California offers an opportunity for profitably prosecuting this study. The following are the lines of such work that have been planned by the Office of Experiment Stations for 1905, with a brief statement why each offers an opportunity for profitable study:

(1) Field experiments in irrigating wheat near Modesto by each of the three standard methods, viz, checks, furrows, and flooding from

field laterals. But very little grain is irrigated in California outside of the extreme southern part of the State, and the experiment is designed to determine if more can not be irrigated with profit. The use, in the experiment, of the three standard methods of applying water will do much to demonstrate which is the best method under the conditions employed. This is an important matter to farmers who are now spending from $10 to $20 per acre in checking land which could better be irrigated in a less expensive way.

(2) A study of the furrow method of irrigation as practiced in southern California. The majority of the orchardists of southern California water their fields by means of furrows. This method has been practiced for more than a quarter of a century by communities noted for their intelligence. It has also been freely discussed by horticultural journals and at farmers' meetings. A subject of such apparent simplicity should be well understood, yet this is far from being the case. Accurate knowledge as to what becomes of the water which is conducted in furrows over orchard tracts is still lacking. The irrigator is left to his own conjectures, for he can find few, if any, who are qualified to answer such inquiries as these: In using 1 miner's inch of water on 5 acres of orchard what percentage is utilized by the trees, how much is lost by evaporation from the soil, and how much percolates through the subsoil and passes beyond the roots of trees? What are the relative merits of shallow and deep furrows? How much more water is evaporated from a wet soil than from a dry soil? To what extent is evaporation lessened by a layer of dry soil above a wet soil? What amount of water will produce the best results and when should it be applied? Problems of this character must be solved for each locality before proper methods of applying water are finally decided upon. The purpose in including this work for next year is to assist the orchardists in solving some of these problems.

(3) A continuation of the investigations of pumping plants along the following lines: (a) Laboratory tests to determine wherein the efficiency of pumping plants may be increased and the cost of pumping water decreased; (b) laboratory tests on a small plant to be installed at Berkeley by the University of California; (c) the testing of a small number of large plants in the field; (d) the cost and value of water derived from typical pumping plants in southern California. It is believed that these investigations of irrigation by pumping, reviewed at some length elsewhere in this report, are bringing to light facts of very great value to the farmer who must raise his water supply from below the surface of the ground. The number who get their irrigation supply in this way has multiplied many times in the past ten years and will increase more rapidly in the future. Tests show that some irrigators are getting more than double the efficiency from the pumps than others are getting. It will be of great value to point out to the less successful

farmer the conditions which he must avoid, as well as the conditions he must seek, if he would derive a high efficiency from his plant. While making these mechanical tests of pumping plants we are endeavoring to watch the economics of pumping as provided for in the last section under this heading. Beginners in irrigation are asking how much pumped water costs, and by continuing these investigations we shall be in a position to answer them.

(4) A study of the details of canal organization and management in California under the following heads: (a) Nature of the different organizations, whether individual, partnership, cooperative, district, or corporate; (b) duties of officers and employees of canal organizations; (c) cooperation among irrigators in the apportionment of water under branch canals and in dealing with canal officers in matters pertaining to the rights and acts of individual irrigators; and (d) the keeping of records of the delivery of water to users. This is a field that, aside from the question of water rights, has been little studied in detail in California, but which is of prime importance, because the ultimate success of any irrigation organization depends upon the relation of the irrigators to the ownership of the water supply and upon the efficiency and faithfulness with which those charged with distributing and dividing water fulfill their duties.

During the past year a study has been made of the organization and management of two important irrigation districts, and it is hoped to make similar, but less extensive, studies of some of the other successful districts, as well as some of the mutual and private companies of the State.

(5) A study of the economy of permanent structures in the irrigation systems of California. All realize that permanence is, in the long run, more economical than makeshift, yet few irrigators, especially under cooperative or district organization, readily consent to the initial investments necessary for making permanent structures. Often a thousand dollars is spent on a temporary structure where a comparatively small increase would pay for a permanent one. The present is an opportune time to point out how money may be saved and irrigation enterprises improved by the introduction of more concrete masonry and steel to take the place of some of the wooden structures now in use. The purpose of this study is not only to show the economical value of a change of policy in this respect, but to point out by means of a few typical designs how the change may be brought about.

(6) A continuation of tank experiments. An equipment for studying, under southern and central California conditions, the relation of soil moisture to plant growth and the loss of water by evaporation is now available. The data already obtained indicate valuable results, but the investigation is entirely new to California, and there is need of collect-

ing considerable data before arriving at definite conclusions regarding the complex questions involved.

(7) Experiments on the cost and efficiency of canal linings. . There are few, if any, canals from which considerable water is not lost and under which much valuable land is not injured or ruined through seepage. How to prevent this is a problem for which no generally satisfactory solution has been found. Individuals or canal organizations can not afford to experiment with the different methods, and there is need of a public investigation to determine the facts. This is now being arranged for.

Recommended for publication.
A. C. TRUE, *Director*.

Publication authorized.
JAMES WILSON,
Secretary of Agriculture.

WASHINGTON, D. C., *December 15, 1904*.

O